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Linear Variable Differential Transformers: Theory, Instrumentation and Installation

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INTRODUCTION

The purpose of this manual is to provide the basic principles of theory and installation associated with linear variable differential transformers to users of the Newmark Structural Engineering Laboratory (NSEL). The material presented in this manual is based on 50 years of experience of NSEL and references listed at the end of this manual. Also, the experience of past users of NSEL was used while working on this manual. Many questions have been asked on which either direct answers were given or references were recommended in which answers could be found. That is why this manual was partially written in the question-answer format. Any critical comments and remarks of current users are also welcomed and they will be used in a future revision. This manual is divided into three sections: Theory, Instrumentation, and Installation.

THEORY

What is a linear variable differential transformer? The linear variable differential transformer (LVDT) is an electromechanical transducer, which allows the measurement of displacement of any movable part. The measured amount of displacement is proportional to the electrical output of the transducer as a resultant of an inductive interaction between a magnetic core and a set of windings: primary winding which is powered by high frequency low voltage current, and two secondary windings usually symmetrically located against the primary one. The secondary windings generate the electrical output correlated to the position of the magnetic core.

Figure 1 shows an example of a commonly used LVDT. The primary winding (8) and the secondary windings (9) are separated by high-density gloss filled polymer coil form (4) and both are encapsulated in epoxy (3). This assembly is covered by stainless steel housing (1), sleeve (6), and end caps (5). The high-permeability magnetic shell (2) is placed between the housing (1), and polymer encapsulation (3), and separators (4). The high-permeability nickel-iron core (7), usually threaded from both ends, is placed inside of the sleeve (6). Carrier (10), which must be non-magnetic, transfers the linear motion of an object to the core (7) and consequently changes the electrical output of the LVDT.

How does the LVDT work? Figure 2 illustrates what happens when the core of the LVDT is in different axial positions. The primary winding, (P) of the LVDT is energized by a constant amplitude altered current (AC) source. The magnetic flux thus developed is coupled by the core to the adjacent secondary windings, (S_1) and (S_2). If the core is located midway between (S_1) and (S_2) (Figure 2b), equal magnetic flux is coupled to each secondary winding so the voltages, (E_1) and (E_2) induced in each winding are equal. At this midway core position, referred to as the null point, the differential voltage output, (E_1 - E_2) is effectively zero. As shown in Figure 2a, if the core is moved closer to (S_1), the induced voltage (E_1) increases while (E_2) decreases, resulting in the differential voltage (E_1 - E_2). Conversely, if the core is moved closer to (S_2) (Figure 2c), more flux is coupled to (S_2) and less to (S_1), and (E_2) is increased as (E_1) is decreased, resulting in the differential voltage (E_2 - E_1). Figure 3a shows the magnitude of the differential output voltage (E_{ACout}) varies with core position. The value of E_{ACout} at

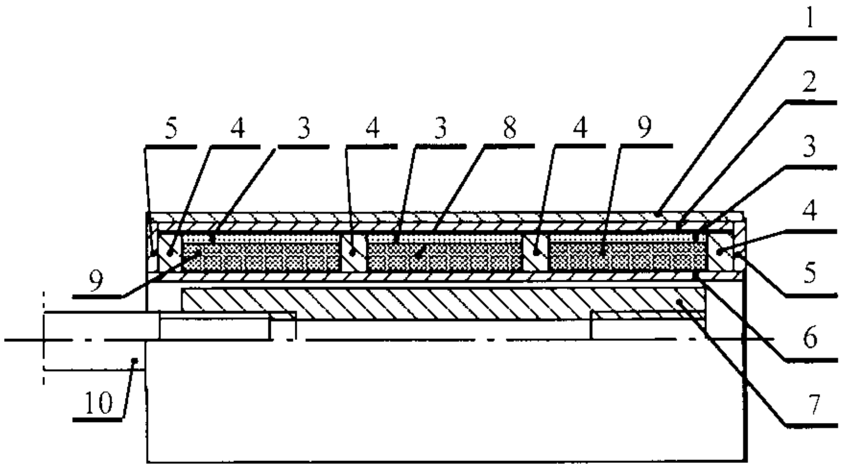


Fig. 1 Half-view half-cross-section of an LVDT: 1. Stainless steel housing, 2. High-permeability magnetic shell, 3. Epoxy encapsulation, 4. High-density gloss filled polymer coil form, 5. Stainless steel end caps, 6. Stainless steel sleeve, 7. High-permeability nickel-iron core threaded on both ends, 8. Primary winding, 9. Secondary winding, 10. Non-magnetic carrier.

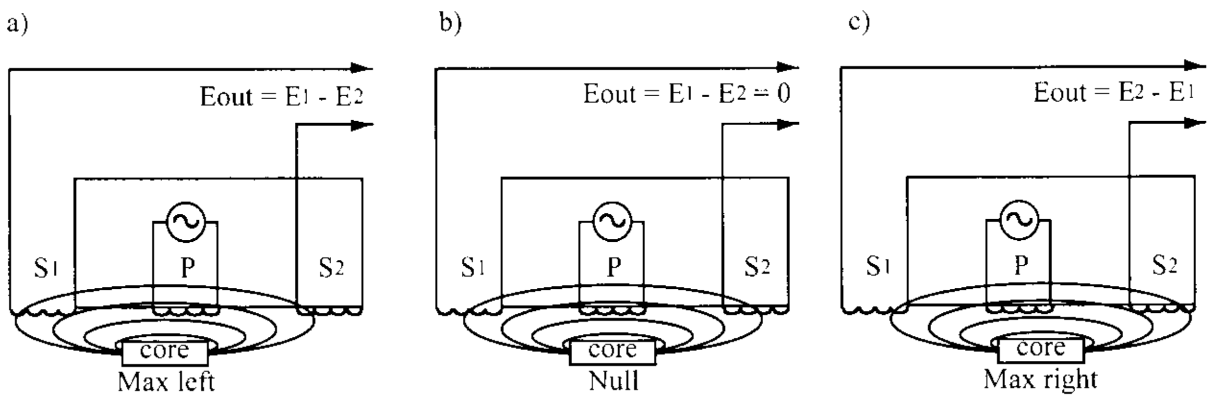


Fig. 2 Schematic diagram of an interaction between core and windings in an LVDT: a) Core is in the maximum left position at which voltage (E_1) is higher than (E_2) due to the higher flux coupled between primary winding (P) and secondary winding (S_1), b) Core is in the midway between secondary windings (S_1) and (S_2); thus equal flux is coupled to each secondary winding and consequently $E_1 = E_2$, c) Core is in the maximum right position at which voltage (E_2) is higher than (E_1) due to the higher flux coupled between primary winding (P) and secondary winding (S_2).

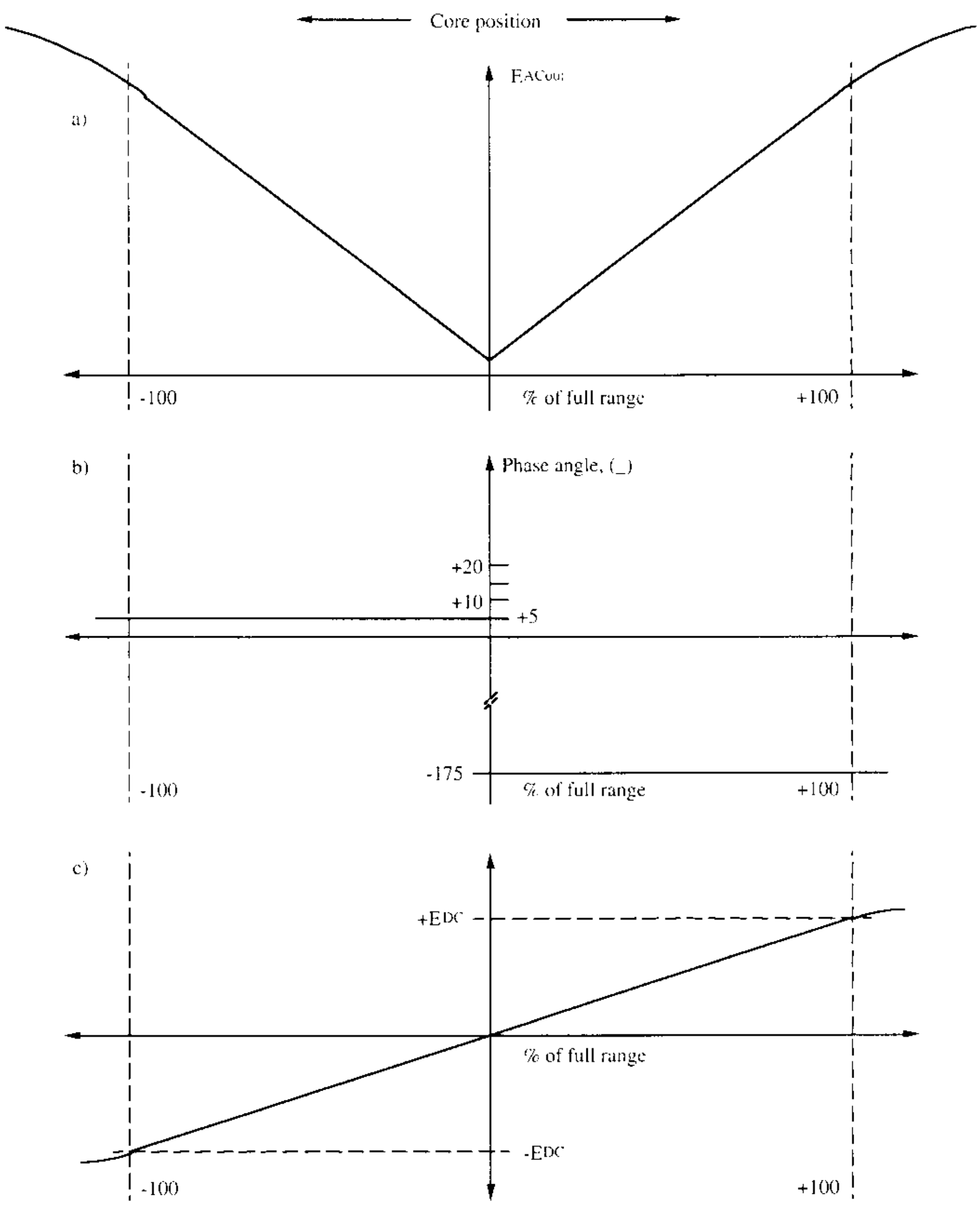


Fig. 3 Output from LVDT: a) Magnitude of differential AC output, b) Phase angle of output relative to primary, c) Magnitude of DC output from signal conditioner.

maximum core displacement from null depends upon the amplitude of the primary excitation voltage and the sensitivity factor of the particular LVDT, but is typically several volts (rms). The phase angle of the AC output (E_{ACout}), referenced to the primary excitation voltage, stays constant until the center of the core passes the null point, where the phase angle changes abruptly by 180°, as shown graphically in Figure 3b. This 180° phase shift can be used to determine the direction of the core position from the null by means of appropriate circuitry. This is shown in Figure 3c, where the polarity of the output signal (E_{DC}) represents the position of the core relative to the null point. It is apparent from this figure that the output from the LVDT is linear over its specified core motion, and that the sensor can be used over an extended range with some reduction in output linearity.

What are the benefits of using an LVDT? The advantages of using an LVDT as opposed to other displacement transducers can be listed as follows:

- *Friction-Free Operation*: There is no mechanical contact between the core and coil assembly of the LVDT, which means it features unlimited mechanical life. Furthermore, the absence of friction permits the LVDT to respond very fast to changes in core position. Only the inertial effects of the slight mass of the core limit the dynamic response of the LVDT sensor.

- *Infinite Resolution*: LVDT is an absolute output device, as opposed to an incremental output device. It measures infinitesimally small changes in core position because it operates on electromagnetic coupling principles. Only the signal conditioner and output display limit the infinite resolution capability of the LVDT. Also due to this capability, the location of the intrinsic null point of the LVDT is extremely stable and repeatable.

- *Single Axis Sensitivity*: LVDT responds to motion of the core along the coil axis, but it is insensitive to radial position of the core. Therefore the LVDT still functions without a problem when the core is misaligned and does not travel in a precisely straight line.

- *Separable Coil and Core*: The coil assembly can be isolated from the core by inserting a non-magnetic tube between the core and the bore. This tube can contain a pressurized fluid when, for example, the LVDT is used for spool position feedback in hydraulic servo valves.

- *Over-travel Damage Resistant*: The internal bore of most LVDTs is open at both ends. In the event of unanticipated over-travel, the core is able to pass completely through the sensor coil assembly without causing damage.

- *Environmentally Robust*: LVDTs have superior resistance to moisture and humidity, as well as to substantial shock loads and high vibration levels in all axes. The internal high-permeability magnetic shield minimizes the effects of external AC fields. The case and core are corrosion resistant and they can be hermetically sealed using a variety of welding processes. LVDTs can operate over a very wide temperature range, from cryogenic temperatures to elevated temperatures and radiation levels found in many nuclear reactors.

What is the difference between (AC-AC) LVDT and (DC-DC) LVDT? Both types of LVDTs work based upon the same principles presented earlier. The (DC-DC) LVDT is an (AC-AC) one with a built in circuitry, which supports the (DC-DC) LVDT using (DC) input that generates (DC) output. The maximum (DC) input voltage varies from 6 to 30 V depending upon the type of LVDT (manufacturer).

What is the basic instrumentation? Although an LVDT is an electrical transformer, it requires AC power of an amplitude and frequency quite different from ordinary power lines to operate properly (typically 3 V rms at 2.5 kHz). Supplying this excitation power for an LVDT is one of several functions of the instrumentation, which is also known as LVDT signal conditioning equipment. Other functions include converting the low level (AC) output of the LVDT into high level (DC) signals that are more convenient to use, decoding directional information from 180° output phase shift as the core of an LVDT moves through the null point, and providing an electrically adjustable output zero level. Figure 4 shows typical diagram representation of LVDT signal conditioning electronics.

INSTRUMENTATION

AC-AC LVDT

There are a number of pieces of LVDT instrumentation available for use at NSEL. A discussion of instrumentation with LPC-2000 of Macro Sensors (Reference 1) is provided in the following paragraphs. The user should also be aware of signal conditioner SCXI-1540 of National Instruments (Reference 3).

LPC-2000 Power Supply and Signal Conditioner

Figure 5a shows a set of six (6) LPC-2000 power supply and signal conditioner modules mounted in the enclosure (blue box) equipped additionally with a voltmeter, power switch, module selector, and output range switch. Figure 5b shows the back of this system with six LVDT bendix connectors and six BNC output connectors. Figure 6 shows the single module, which supports given AC-AC LVDT. The LPC-2000 is a compact, single channel AC-operated signal conditioner capable of providing conditioning of most LVDTs. Operating at 110-220 V, 50-60 Hz, the LPC-2000 provides all necessary circuitry required to operate the position sensor and provide a high level, reduced noise analog DC output at the range of ±10 V, which is suitable for feeding analog or digital control indicators, Programmable Logic Controllers and other system indicating and control instrumentation. The LPC-2000 module is also capable of generating a 4-20 mA loop output. Instruction manual for LPC-2000 is available in Reference 1.

Operation of the LPC-2000 and AC-AC LVDT

1. Connect the LPC-2000 power supply and signal conditioner (blue box) to the 110 V, 60 Hz source of electrical power. Flip the toggle switch "POWER" on the power supply (Figure 5a). Wait at least 5 minutes (warm-up time) before proceeding to step 2.

2. Turn the "LVDT SELECT" to channel 1 (Figure 5a). Switch the "METER RANGE" to 2 V range (Figure 5a). Plug in the jumper shown in Figure 7 into the outlet 1 (Figure 5b). Using

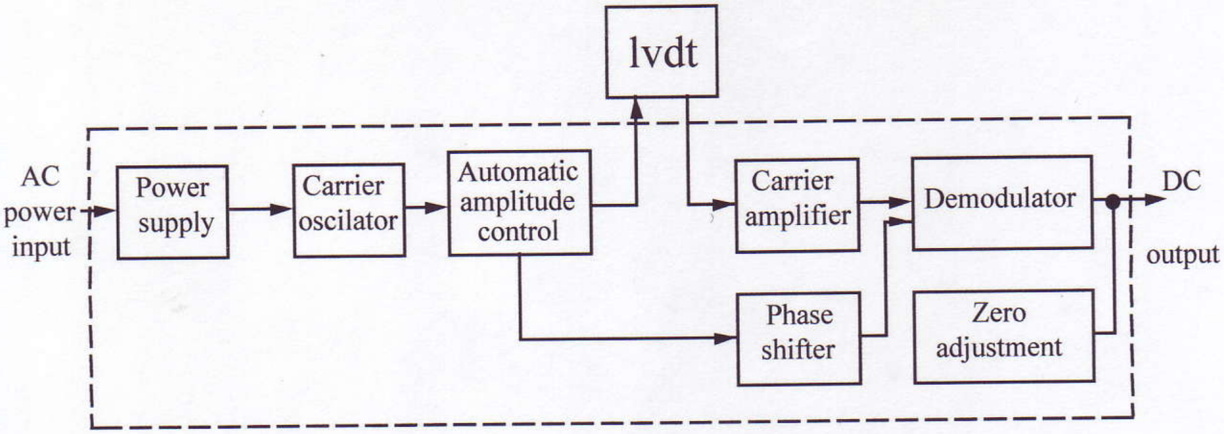


Fig. 4 LVDT support electronics diagram.

a)

b)

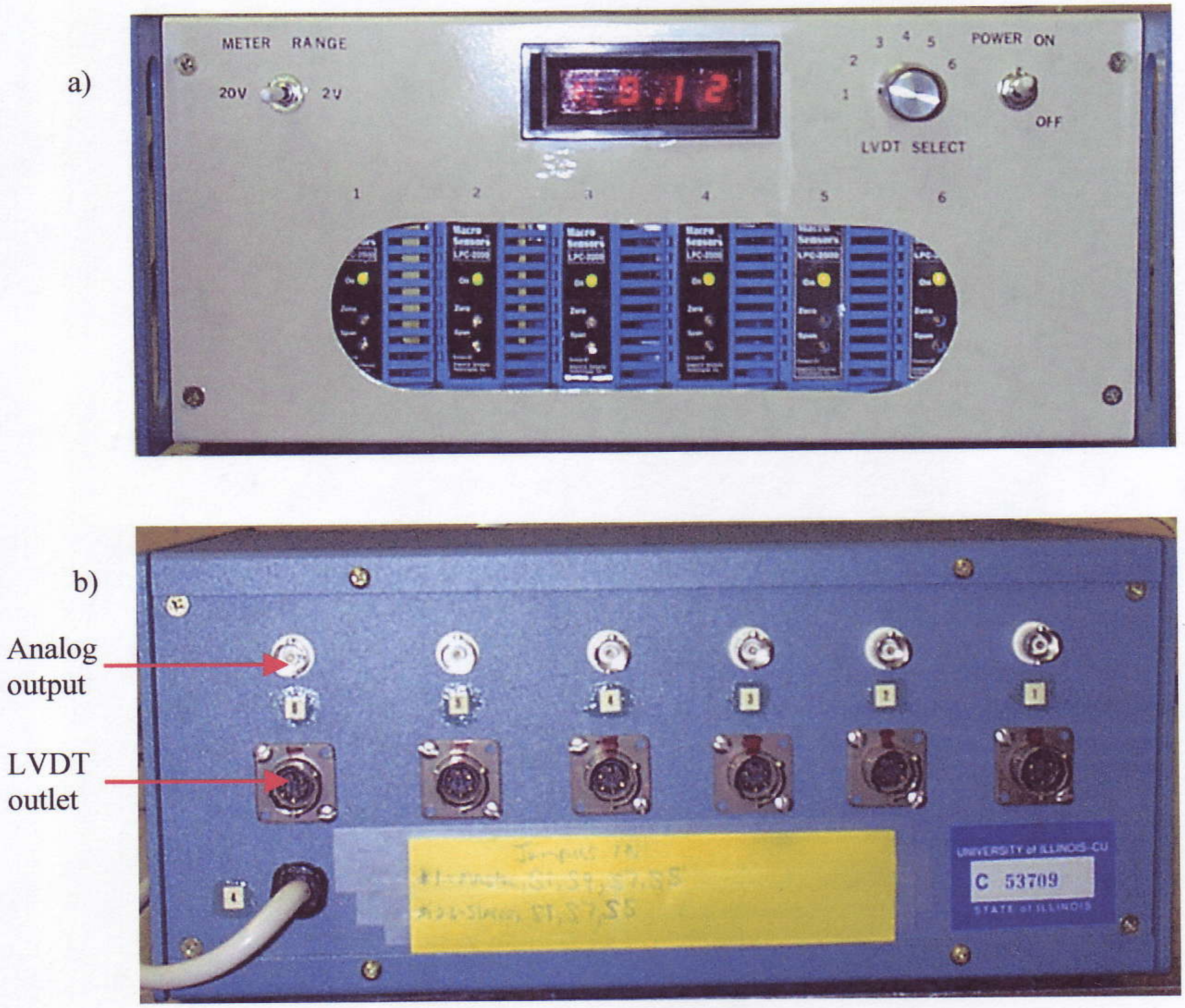


Fig. 5 Six Macrosensors' LPC 2000 modules in blue box for use with AC-AC LVDTs: a) Front view, b) Rear view.

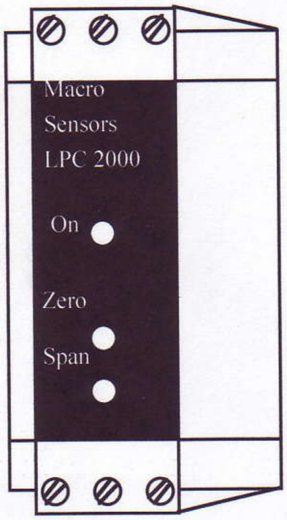


Fig. 6 A module of Macrosensors' LPC 2000
for use with AC-AC LVDT.

Fig. 7 Jumper.

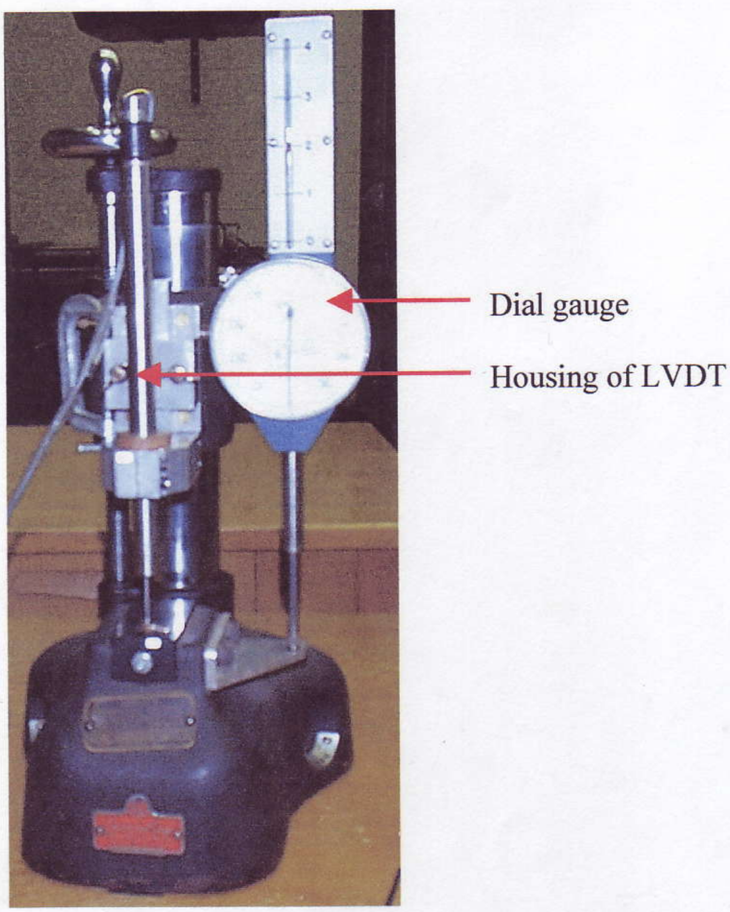


Fig 8. Calibrator.

the "Zero" resistor (Figure 6) and a small screwdriver adjust the "METER" reading to 0.000 V. This means that the amplifier of the channel 1 generates 0.000 V output. Repeat this operation for all channels to be used.

3. Switch the "METER RANGE" to 20 V range (Figure 5a). Remove the jumper from outlet 1 (Figure 5b) and plug in the LVDT connector instead. Mount the LVDT into the calibrator (Figure 8). Move the housing of LVDT up and down until the zero V (0.00 V) output is achieved. This means that the electrical zero (null) of LVDT was found. Set the dial gauge of the calibrator also to zero. Move the housing of LVDT to its full range, e.g. 1 in. Using small screwdriver, adjust the "SPAN" resistor (Figure 6) until either -10.00 V or +10.00 V is achieved (the sign depends upon the direction of motion of the LVDT housing. Take output voltage readings every 10% of the LVDT readings; e.g. for ±1 in. LVDT, 0.1 in. interval should be used. Take the readings going in both positive and negative directions.

4. Plot the data output voltage versus displacement and obtain the least square equation which could be used during experimental data reduction.

5. Repeat steps 3 and 4 for each LVDT to be used at each channel. The blue box supports a maximum of six channels.

6. Each blue box has a set of six analog outputs (Figure 5b), which can be used for either calibration or data logging.

DC-DC LVDT

Since each DC-DC LVDT has a built-in circuitry, which is an equivalent of LPC-2000, any DC power supply can be used for its operation. An example of DC power supply is shown in Figure 9.

Operation of DC Power Supply and DC-DC LVDT

1. Connect a DC power supply to the 110 V, 60 Hz source of electrical power. Turn it on (Figure 9) and wait at least 30 minutes (warm-up time) before proceeding to step 2.

2. Adjust the output DC voltage (excitation voltage) from the power supply to the value specified by the LVDT manufacturer; usually it is between 6 V and 30 V. Connect the output from DC power supply to the transition box shown in Figure 10. Make sure that the polarity is correct; minus goes to minus and plus goes to plus. If the polarity is reversed, the output from LVDT will be close to zero.

3. Connect the LVDT to one of six channels of the transition box (Figure 10a). Also connect a voltmeter to the transition box (Figure 10b). Mount the LVDT into the calibrator (Figure 8). Move the housing of LVDT up and down until the zero V (0.00 V) output is achieved. Set the dial gauge of the calibrator also to zero. Apply the full range of displacement to the LVDT. Adjust the excitation voltage in such a way that 10 V output from the LVDT is achieved. Move the LVDT back to its zero position and apply the full range in the opposite direction. The output voltage should be equal or less than 10 V. If it is higher than 10 V, reduce the excitation voltage in such a way that output of 10 V is achieved. Move the

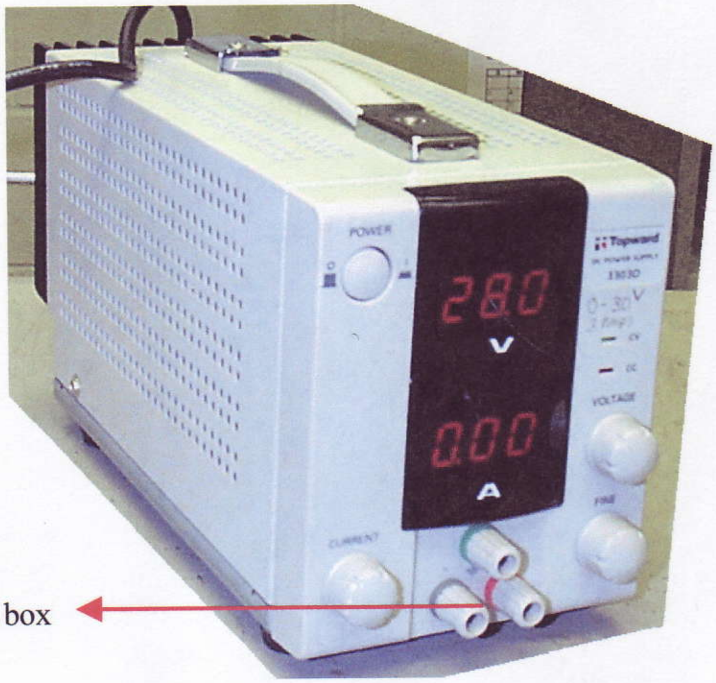


Fig. 9 DC power supply.

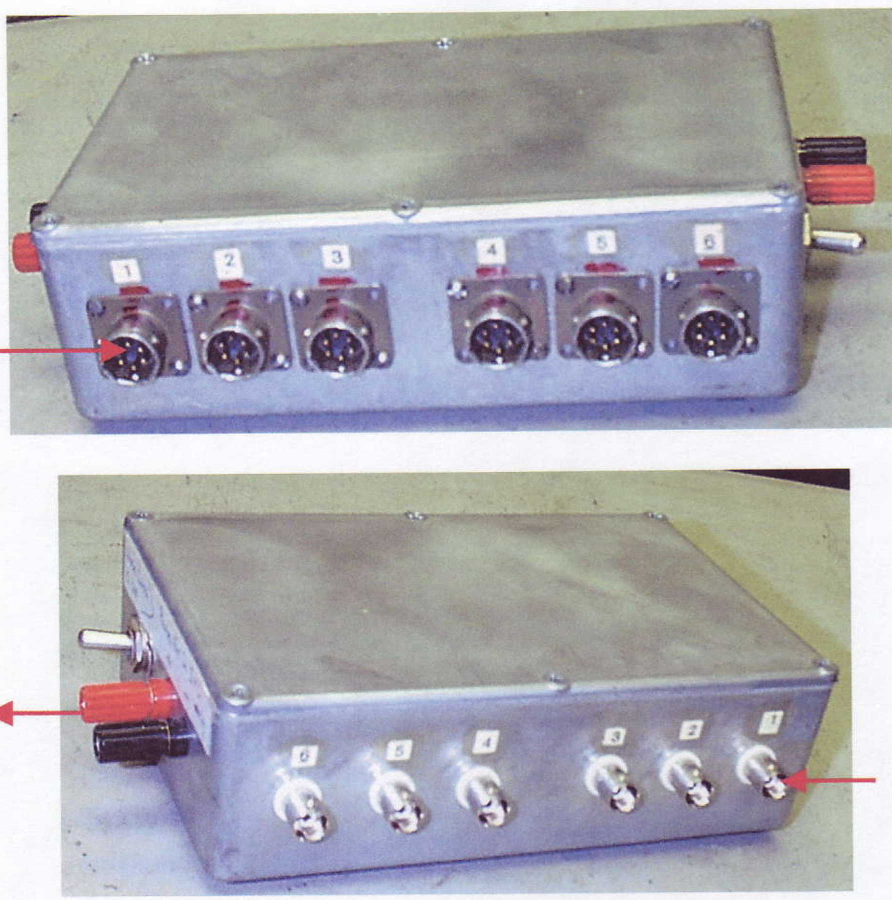


Fig. 10 Transition box: a) Front view, b) Rear view.

LVDT back to its zero position. Calibrate the LVDT by applying an interval of displacement equal to 10% of the full range of LVDT; e.g. for ±1.0 in. LVDT, the interval is equal to 0.1 in.

4. Plot the calibration data in the displacement-voltage coordinates. Using the least square linear regression method, determine the equation $\delta = f(U_{out})$ where δ is the displacement (in.) and U_{out} is the output voltage (V) from the LVDT. An example of the calibration line is shown in Figure 11 where r is the correlation coefficient.

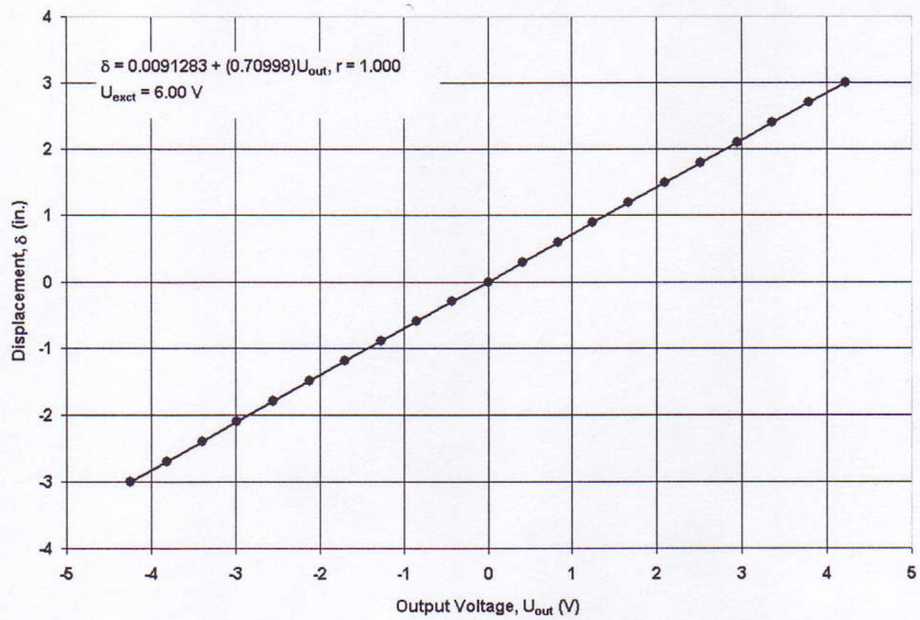


Fig. 11 An example of calibration data for +/- 3.0 in. DC-DC LVDT.

INSTALLATION

<u>What things should be considered when mounting LVDTs</u>?

- Mounting fixtures, core extension rods, and hardware located within an inch of the LVDT should be made of nonferrous materials that are poor electrical conductors. This is to avoid compromising LVDT performance by changing its magnetic field or by enabling eddy currents that work against this magnetic field. Preferred materials are nonmagnetic stainless steels and engineering plastics. Nonmagnetic materials such as aluminum, brass and copper may also be used provided the mass is small and the material is split axially to impede eddy currents concentric to the LVDT.

- The body of the LVDT should be securely fastened by clamping the housing in a split block or similar fixture. NSEL has split blocks made of a composite material called Kevlor (Figure 12a). These nonmagnetic blocks can be machined easily for a particular test application and for different diameters of LVDT housing. Figure 12b shows an LVDT inserted into a Kevlor block. Clamping the body of the LVDT near its electrical center will minimize zero shift with temperature.

- The core should be positioned to allow free movement through the entire measurement range of the LVDT. With proper alignment, the core will not contact the bore, resulting in frictionless operation. If the contact is significant, frictional wear will result in non-linearity and degradation in sensitivity.

Fig. 12a Kevlor split block.

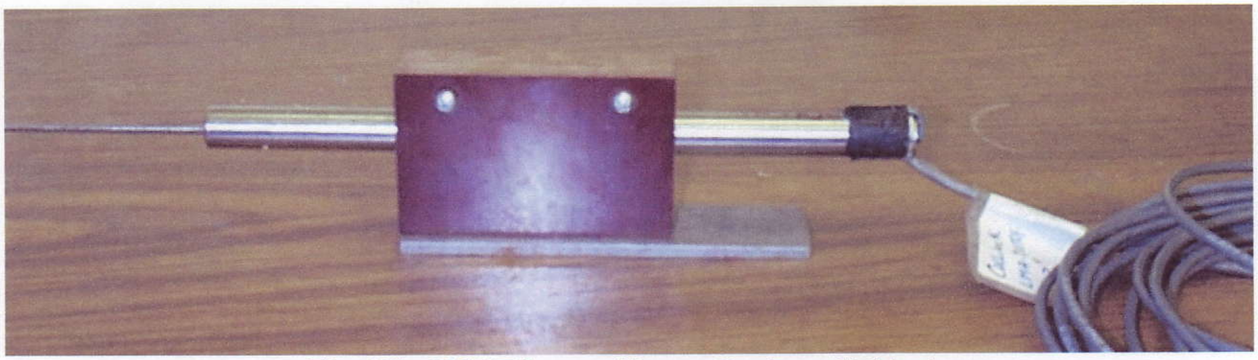


Fig. 12b LVDT inserted into a Kevlor split block.

LVDTs being used to determine displacements of a model frame, with the outer casing of each LVDT attached to an auxiliary supporting frame and the movable cores attached in a spring-loaded fashion to the model, are shown in Figure 13a. The LVDT can also be adopted to act as a strain gauge to monitor strains over a moderate or extended gage length as shown in Figure 13b. Other applications of LVDTs are shown in Reference 2.

The range and number of LVDTs available at NSEL can be found at our website: http://cee.ce.uiuc.edu/nsel/Facility/lvdt.htm.

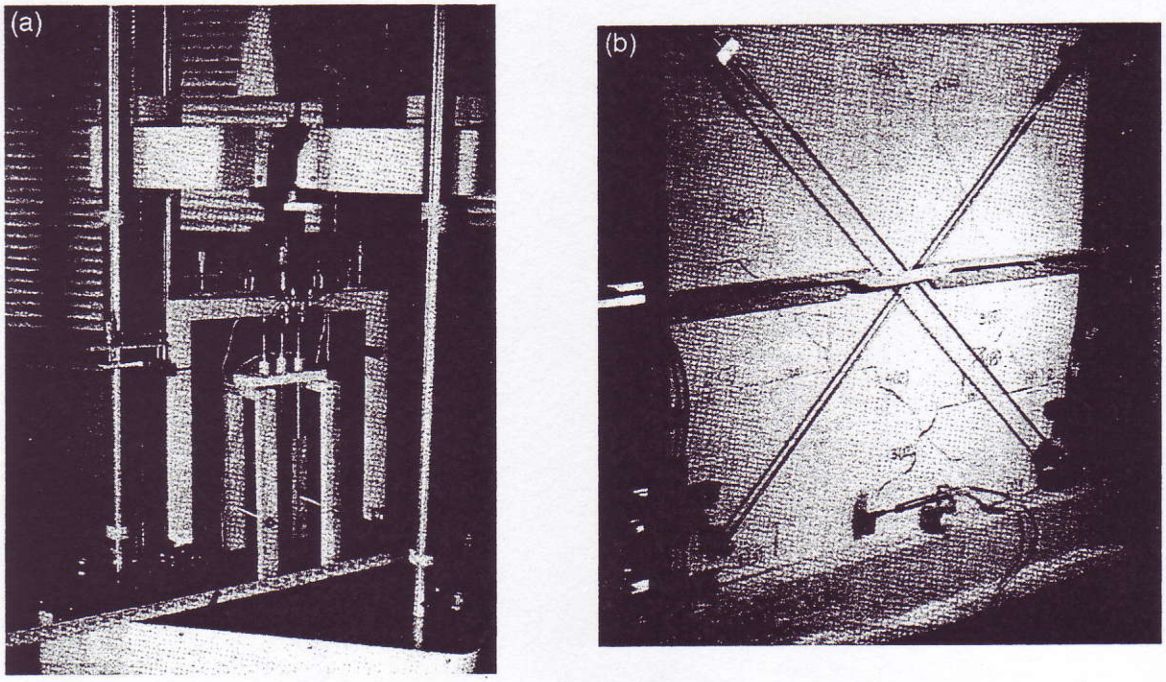


Fig. 13 Use of LVDTs in measuring displacements and strains: a) LVDTs for deflection measurements, b) LVDTs for strain measurements.

REFERENCES

Ref. 1 *Instruction Manual.* Line Power Operated LVDT Signal Conditioner, Model LPC-2000 (included).

Ref. 2 Handbook of Transducer Design, Engineering and Application, Trans-Tek Inc (partly included).

Ref. 3 SCXI-1540 User Manual, 8-Channel LVDT Signal Conditioner, National Instruments, March 2000 Edition.

Ref. 4 Harris, H. G. and Sabnis, G. M. Structural Modeling and Experimental Techniques, Second Edition, 1999, p. 348-352.

Ref. 5 Herceg, E. E. Handbook of Measurement and Control, published by Schaevitz Engineering, 1972.

Ref. 6 Lion, K. S. Instrumentation in Scientific Research, published by McGraw-Hill Book Company, Inc., 1959.

Ref. 7 Ramsay, D. C. Principles of Engineering Instrumentation, published by Halsted Press, 1996.

Ref. 8 http://www.macrosensors.com

Ref. 9 http://www.sentechlvdt.com

Ref. 10 http://www.transtekinc.com

Reference 1

Instruction Manual
Line Power Operated LVDT Signal Conditioner
Model LPC-2000

Macro Sensors™

Division Of
Howard A. Schaevitz Technologies, Inc.

7300 Industrial Center, Bldg. 22
U.S. Route 130 North
Pennsauken, NJ 08110-1541

Phone: 856-662-8000 **FAX: 856-317-1005**

DESCRIPTION

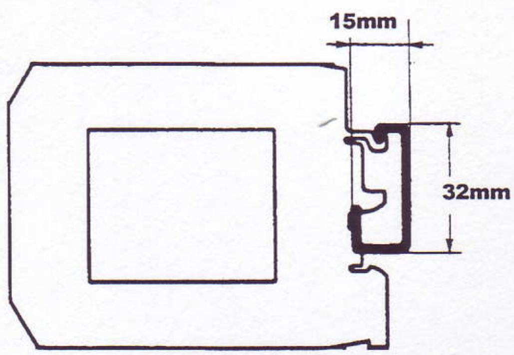
The LPC-2000 is a compact single channel AC-line powered signal conditioner capable of operating most LVDTs and RVDTs. Operating from 115 V or 220 V AC, 50-60 Hz, an LPC-2000 provides all circuitry required to operate an LVDT position sensor and provide a high level, low noise analog DC output suitable for feeding analog or digital indicators, PLCs, and other system indicating and control instrumentation or a 4-20 mA 3-wire current loop output.The LPC-2000 features user-selectable excitation frequency and gain to function with sensors having widely different sensitivities. Connections are made via recessed screw terminals at the top and bottom of the case, which mounts on DIN 1 or DIN 3 rail.

SPECIFICATIONS

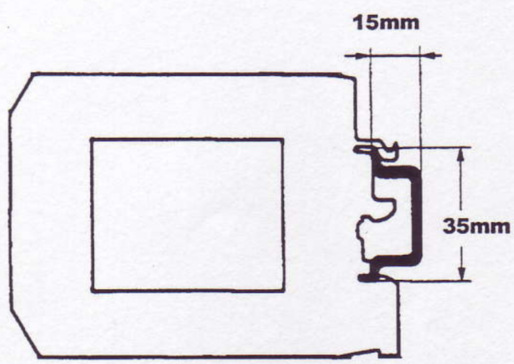
Power Input Voltage........115 or 220 V AC, 50-60 Hz, 2.5 VA
LVDT Excitation Voltage...................................3 V rms (Nom.)
LVDT Excitation Frequency..................3 kHz, 5 kHz or 10 kHz
LVDT Primary Impedance..............................200 Ohms (min.)
Output, Voltage Mode...................................±10 V DC @ 5 mA
Output,Current Mode...........4-20 mA sourcing, 300 Ohms max
Frequency Response...-3 db at 250 Hz
Output Ripple...<10 mV rms
Output Impedance...<10 Ohms
Nonlinearity..±0.01% FSO
Operating Temp. Range..........0°F to +160°F(-18°C to +70°C)
Temp. Coeff. of Sens..........0.01% FSO/°F (0.018% FSO/°C)
Controls...Zero and Span
Weight..7 ounces (200 grams)

MOUNTING

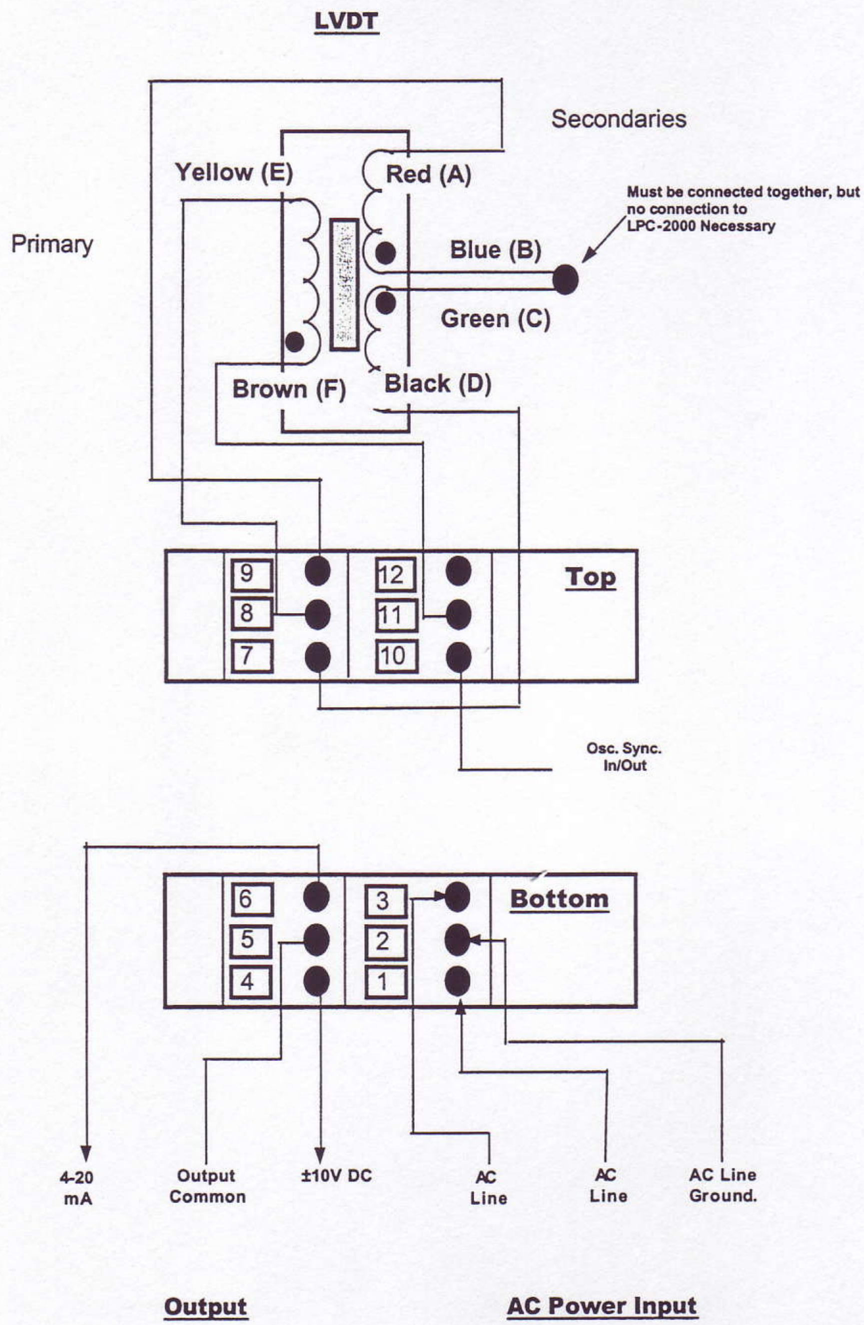
The LPC-2000 is designed to mount on the DIN rail mounting system, including DIN 1, 32mm X 15mm asymetrical, or DIN 3, 35mm X 7.5mm or 15mm symmetrical, rails as illustrated below.



DIN 1 Mounting



DIN 3 Mounting



Wiring Note: The wire colors and/or letters shown in the connection diagram apply only to Macro Sensors' standard AC LVDTs with 6 lead wires or 6-pin connectors. For LVDTs with other terminations such as BB series gaging probes or SQ series heavy duty LVDTs, or for extension cables used with LVDTs, consult the data sheet accompanying the LVDT or cable for the correct color codes or terminal connections. Connect the LVDT's primary and secondaries to the signal conditioner according to the wiring diagram, observing the magnetic polarity dots on the LVDT winding schematic.

CONNECTIONS

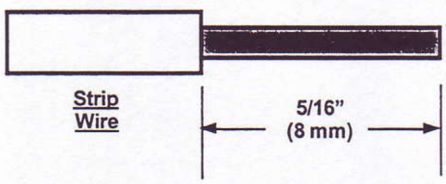
All wire connections to the LPC-2000 are through industry standard recessed screw clamp terminals that will accept wire sizes from #28AWG to #12 AWG, either solid or stranded. Wires should be stripped 5/16" (8 mm) which will provide the proper length of conductor without exposing any bare wire. Line power input wiring should utilize a minimum size of #18AWG. **Be sure to de-energize power line prior to making power connections.**

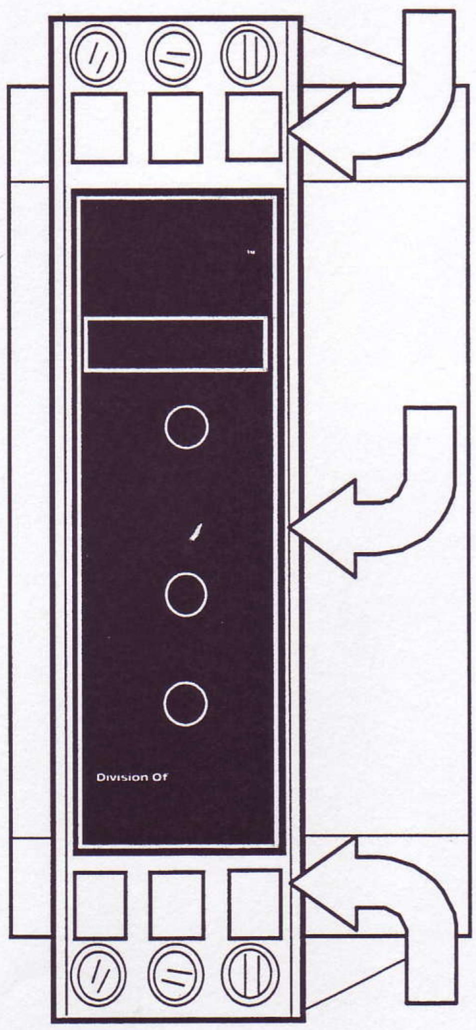
INTERNAL ACCESS

It may be necessary to gain access to the inside of the LPC-2000 to adjust excitation frequency and/or gain jumpers. **De-energize line power.** Using a knife blade, small screwdriver or similar tool, gently pry off the cover at points indicated in figure below.

WARNING !

Dangerous voltages are present inside energized unit ! Be sure to de-energize unit prior to removal of cover !





EXCITATION FREQUENCY SELECTION

The LPC-2000 has three user-selectable LVDT excitation frequencies. The desired frequency is normally set to match the specifications and/or recommended operating frequency of the LVDT being used. As shipped from the factory, the unit is set for 3 kHz excitation frequency which is common to many LVDTs. Frequency is changed by jumpers (shorting bars) on S1, S2 and S3. (see Figure 1). As supplied, a jumper is positioned across S1 as shown in Figure 1. To obtain 5 kHz, move the jumper from S1 to S2. To obtain 10 kHz, move the jumper from S1 to S3. **WARNING!** **Unit must be de-energized when cover is removed. Dangerous voltages are present inside energized unit !**

OUTPUT GAIN SELECTION

The LPC-2000 can operate with LVDTs having a wide range of sensitivities. Coarse gain selection is provided to permit operation with most LVDTs. To set coarse gain, the full scale AC output of the LVDT being used must first be determined by performing the following calculation:

Sensitivity in V olts/.001" X Excitation Voltage X Full Stroke in thousandths of an inch = Full Scale Output (V AC rms)

Example 1: ±0.050" Stroke LVDT
Sensitivity: 0.0065 V/.001" X 3 V rms X 50 (1/2 range in .001") = 0.975 V AC rms Full Scale LVDT Output

Example 2: ±1.000" Stroke LVDT
Sensitivity: 0.00065 V/.001" X 3 V rms X 1000 (1/2 range in .001") = 1.95 V AC rms Full Scale LVDT Output

Gain may be adjusted by placing jumpers S4, S5, S6, and S7 (shorting bars) in positions shown in the table below. Placing jumpers as instructed will yield a ±10 V DC output at full scale LVDT displacement.

GAIN SELECTION TABLE

LVDT Full Scale Output AC Volts	S4	S5	S6	S7
0 - 0.3V	Open	Open	Open	Open
0.31V - 0.6V	Open	**Jumper**	Open	Open
0.61V - 2.5V	Open	**Jumper**	Open	**Jumper**
2.51V - 5.5V	**Jumper**	Open	**Jumper**	Open

Indicates Jumper positions as shipped from factory

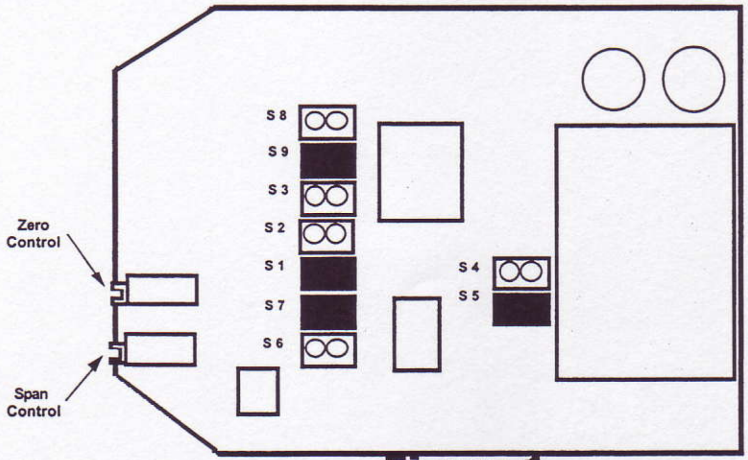
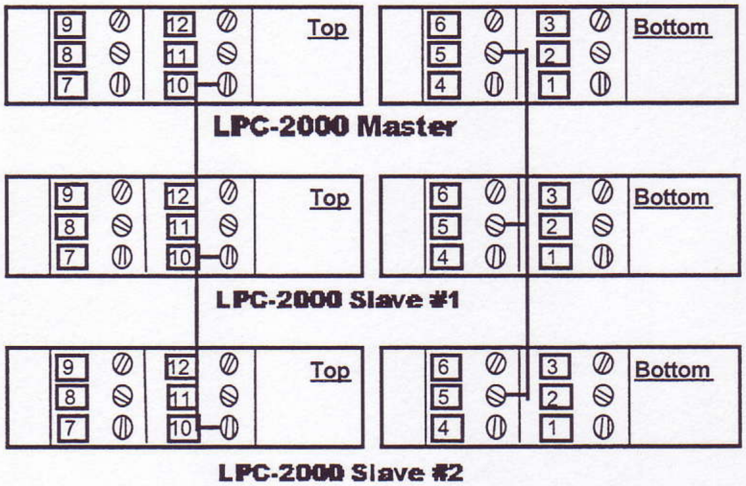


Figure 1

MULTI-CHANNEL APPLICATIONS

A requirement may exist where multiple LPC-2000s are to be used and where units or wiring will be located in close proximity to each other. The LPC-2000 can synchronize the oscillators of multiple units to prevent crosstalk, beating, and intermodulation between units. To synchronize the oscillators, connect together terminal 5 on all units and connect together terminal 10 on all units. These connections are in addition to the connections shown on page 3. One unit should be designated as the "Master" and the balance of the units designated as "Slaves". The "Master" unit's excitation frequency must be set in accordance with the instructions given in the paragraph entitled "Excitation Frequency Selection". On the "Master" unit, move jumper from S8 to S9. "Slave" units must have a jumper (shorting bar) on S8 and all jumpers (shorting bars) must be removed from S1, S2, S3 and S9.



Additional Connections For LPC-2000 Multi-channel "Master/Slave" Configuration

CALIBRATION PROCEDURE (Voltage Output)

To calibrate, remove LVDT secondary wire, usually Red or (A) from terminal 9. Insert temporary jumper between terminals 7 and 9 (this jumper will be removed after Zero adjustment). Apply AC power to unit and allow a 3-5 minute warm-up. Adjust the Zero control until an output of 0 V DC is obtained between terminals 4 and 5. De-energize unit and remove temporary jumper from between terminals 7 and 9. Re-connect secondary wire Red or (A) to terminal 9. Apply power to unit and move LVDT core or body until an output of 0 V DC is obtained. This position is the true null of the sensor and the reference point from which subsequent position measurements are made.

NOTE: If mechanical adjustment of the core or LVDT body is difficult or impossible, make this adjustment as close as possible and then adjust the Zero control to obtain 0 V DC output. It is important that the LVDT be within 5% of its true null position to ensure that full displacement is within the LVDTs rated linear range. Offsets of more than 5% may result in non-linear results at or near full scale displacement.

Move the LVDT core to its full scale displacement and adjust the Span control to obtain a reading of 10 V DC. Outputs of less than 10 V DC may be obtained by adjusting the Span control (e.g. 5 V DC). If desired full scale output cannot be obtained by Span control adjustment, reset gain jumpers (shorting bars) to next higher or lower setting as shown in "GAIN SELECTION" table on page 5 and then re-adjust Span control to obtain desired output. If it is necessary to reset gain jumpers. **Be sure to de-energize unit prior to removing cover.**

Unit is now ready for normal operation.

CALIBRATION FOR 100% ZERO OFFSET (Voltage Output)

100% zero offset allows the user to obtain a unipolar output over the full range of the LVDT.

Follow the instructions as described in the "CALIBRATION PROCEDURE" section for full scale use, but adjust the Span control for half the desired full scale output (e.g. 5 V DC). Move the LVDT core to "minus" full scale displacement and adjust the Zero control to obtain zero output. Move the LVDT core to "plus" full scale displacement and adjust the Span control for desired full scale output. Repeat this procedure to ensure proper calibration.

Unit is now ready for unipolar operation.

CALIBRATION FOR 4-20mA CURRENT LOOP OUTPUT

To calibrate unit for current output, make sure that current loop connections are made between Terminals 5 and 6. Remove LVDT secondary wire, usually Red (A) from Terminal 9. Insert temporary jumper between terminals 7 and 9 (this jumper will be removed after zero adjustment). Apply AC power to unit and allow a 3-5 minute warm-up. Adjust Zero control until a reading of 12 mA is obtained. De-energize unit and remove jumper from between Terminals 7 and 9. Re-connect secondary wire Red (A) to Terminal 9. Apply power to unit. Move LVDT core or body until 12 mA output is obtained. This position is the true null position of the sensor and the point from which subsequent measurements are made.

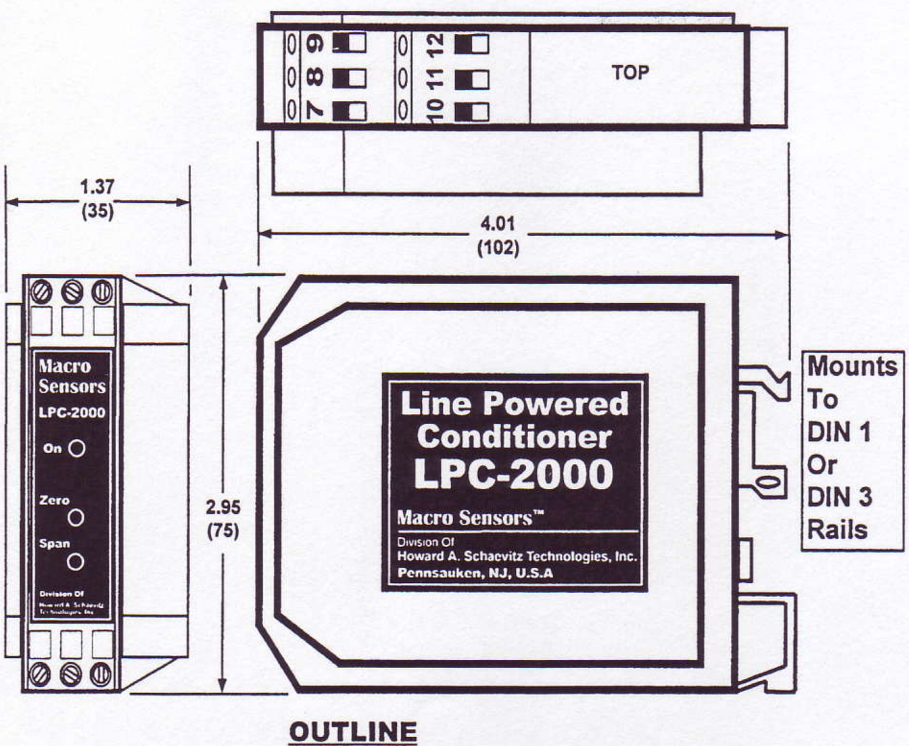
NOTE: If mechanical adjustment of the core or LVDT body is difficult or impossible, make this adjustment as close as possible and then adjust the Zero control to obtain 12 mA output. It is important that the LVDT be within 5% of its true null or zero position to insure that full displacement is within the LVDTs rated linear range. Offsets of more than 5% may result in non-linear results at or near the full scale displacement.

Move the LVDT core to its "plus" full scale displacement and adjust the Span control to obtain a reading of 20 mA. Return the core to "minus" full scale position and adjust the Zero control to obtain a reading of 4 mA. Move the core to the "plus" full scale position and adjust the Span control to obtain a 20 mA reading. Repeat above procedure to ensure proper output at both extremes of the core travel.

Unit is now ready for normal current output operation.

Directional Sense

If the slope of the analog output voltage or current is the reverse of the desired slope, i.e., if the output voltage or current increases or decreases opposite to the desired direction of core motion, reverse the LVDT connections to terminals 7 and 9.



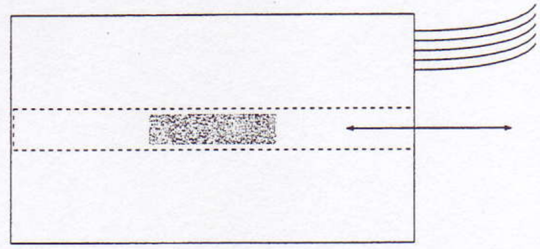
OUTLINE

Reference 2

LVDT - Linear Variable Differential Transformer

Technology

Trans-Tek designs and manufactures a broad line of linear displacement transducers using LVDT technology. An LVDT, or Linear Variable Differential Transformer, is an inductive device containing primary and secondary coaxial wound coils and a ferromagnetic core. Exciting the primary coil with an AC voltage generates an electromagnetic field. The core links the electromagnetic field of the primary coil to the secondary coils, inducing a voltage in each. The secondary coils are typically wired in series opposition, producing AC voltages 180 degrees out of phase with each other. The magnitude of the voltage in each secondary depends on the position of the core relative to the coils.



NON-CONTACTING CORE

By design, the core does not make contact with the inner diameter of the coils with proper alignment. This very important design detail provides frictionless movement of the core through the inner bore of the coils creating infinite mechanical life. Applications demanding high reliability and low failure rates benefit from this basic design feature.

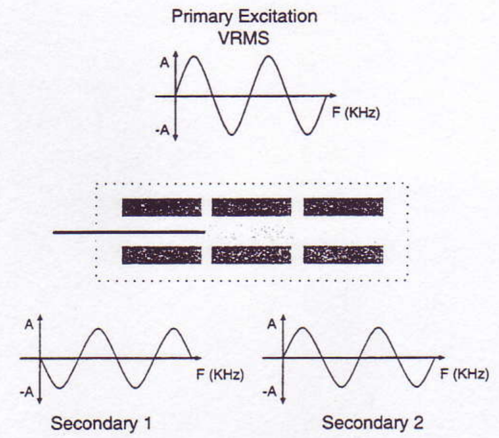
INFINITE RESOLUTION

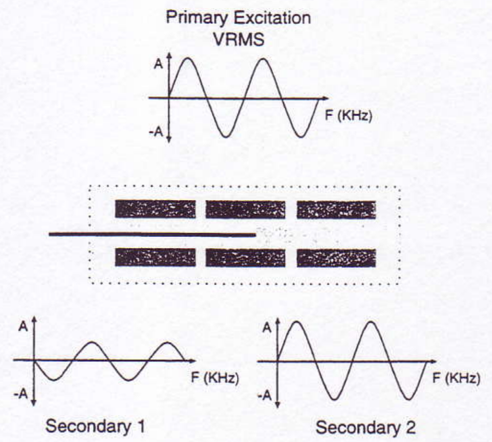
As an analog device, theoretical resolution can be defined as infinite. Resolution is the smallest increment of movement detectable between the core and coils.

NULL POSITION

When the physical center of the core is in line with the electrical center of the coils, the voltage induced in each secondary is equal in magnitude, but opposite in phase. When summed, the secondary voltages cancel each other, resulting in zero output volts. This is the **null** position of the LVDT.

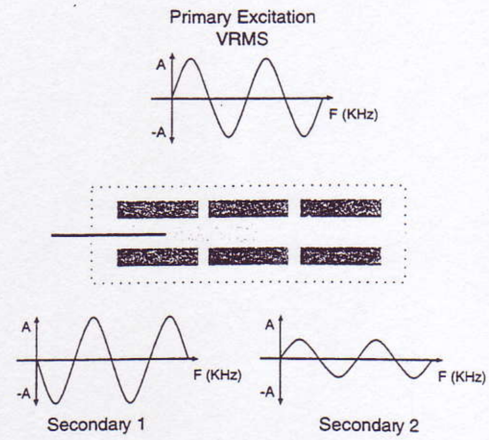
This inherent symmetry in the LVDT construction allows for a highly repeatable null position. Many LVDT applications revolve around this one feature, especially in closed-loop control systems.





CORE MOVEMENT

An LVDT is designed to have symmetric measurement ranges on each side of null. As the core moves to one side of the null position, the magnitude of one secondary becomes greater than the other. Combining the two secondary voltages results in an output voltage proportional to the core's distance from null. The phase of this voltage indicates which side of null the core is located.

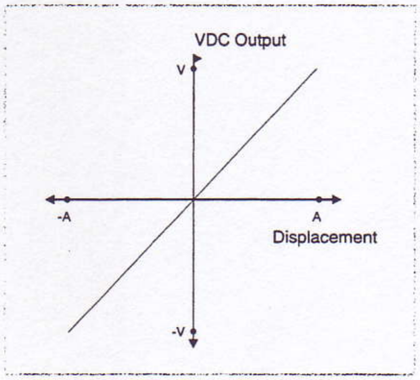


DC-DC LVDT - INTEGRAL SIGNAL CONDITIONING

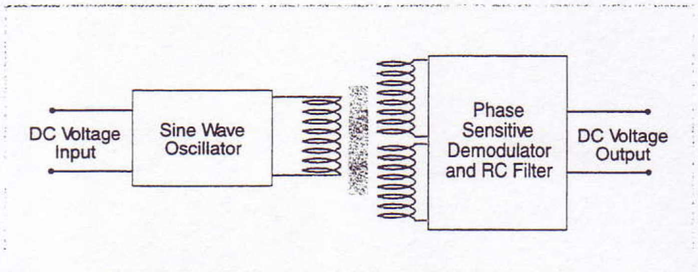
Signal conditioning is an important consideration when designing an LVDT into an application. Converting the AC output voltage of the secondaries into a usable DC output voltage requires a demodulator and low pass filtering. Design of the circuitry must take into account frequency response and electrical noise considerations. For convenience and ease of use, Trans-Tek manufactures a complete line of DC-DC LVDTs, also known as DCDTs, containing an integral oscillator/demodulator.

Discrete components make up the integral signal conditioner. The oscillator converts the DC voltage input to a high frequency AC voltage, powering the primary coil. A passive demodulator circuit rectifies the AC voltage output from the secondaries and differences the resulting signal before filtering with a low pass RC filter. The magnitude and polarity of the DC output voltage are dependant on the position of the core relative to the null position.

OUTPUT VS. DISPLACEMENT



DC LVDT BLOCK DIAGRAM



Trans-Tek's DC LVDTs are input polarity protected, meaning that polarity of the input leads must be observed for proper operation, but the unit will not be damaged by polarity reversal. The DC voltage input can range from 6 to 30 VDC, and must be regulated for best accuracy. The magnitude of the output voltage is controlled by the input voltage. These DC LVDTs also feature input and output circuits isolated both from each other and the coil housing. The result is a transducer which can be used in a floating or ground return system.

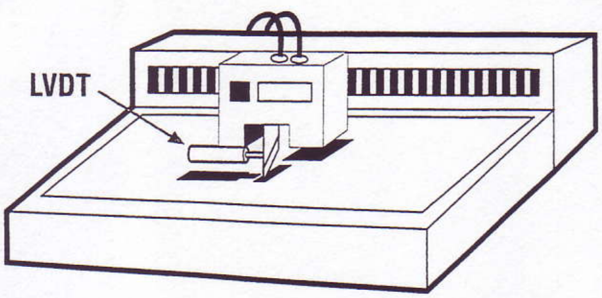
LVDT MOUNTING GUIDELINES

Mounting fixtures, core extension rods, and hardware which are located within an inch of the transducer should be made of nonferrous materials that are also poor electrical conductors. This is to avoid compromising transducer performance directly by changing the shape of the unit's magnetic fields or indirectly by enabling eddy currents which work against the unit's magnetic fields. Preferred materials include nonmagnetic stainless steels and engineering plastics. Nonmagnetic materials such as aluminum, brass and copper may be used provided the mass is small and the material is split axially to impede eddy currents concentric to the LVDT. Iron and magnetic steels should be avoided.

The body of the LVDT should be securely fastened by clamping the housing in a split block or similar fixture. The use of set screws should be avoided, as this may damage the LVDT. Clamping the body near the electrical center, E_C, will minimize zero shift with temperature. The core should be positioned to allow free movement through the LVDT's entire measurement range. With proper alignment, the core will not contact the bore, resulting in frictionless operation. Contact between the core and the bore will not immediately affect transducer performance, however, significant frictional wear will result in a degradation in sensitivity and non-linearity.

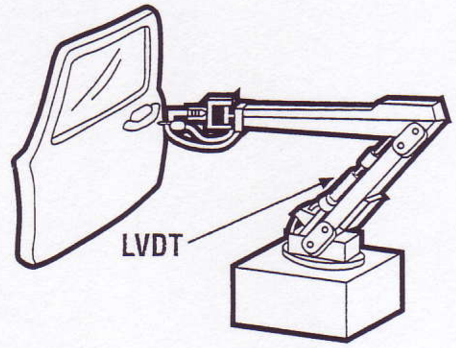
LVDT
Applications

Knife Intelligence for Garment Machine



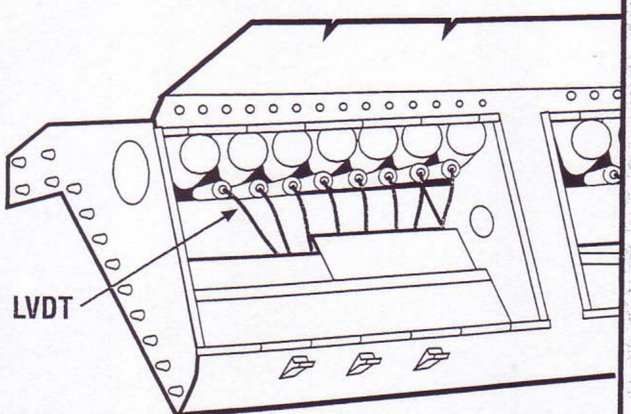
Monitors position of knife blade during fabric cutting process, allowing for actuated correction.

Automotive Parts Assembly



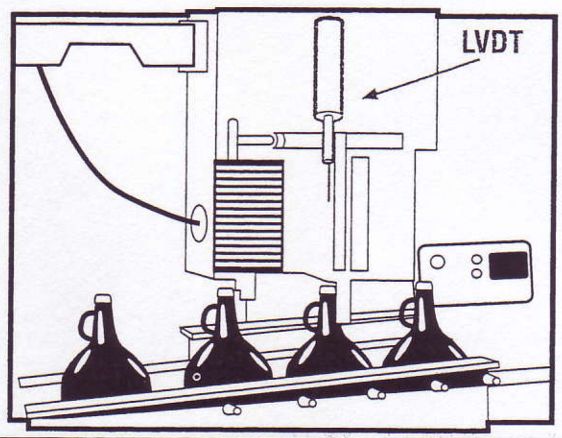
Used on automation equipment to ensure proper alignment of parts prior to assembly.

Paper Machine Activators



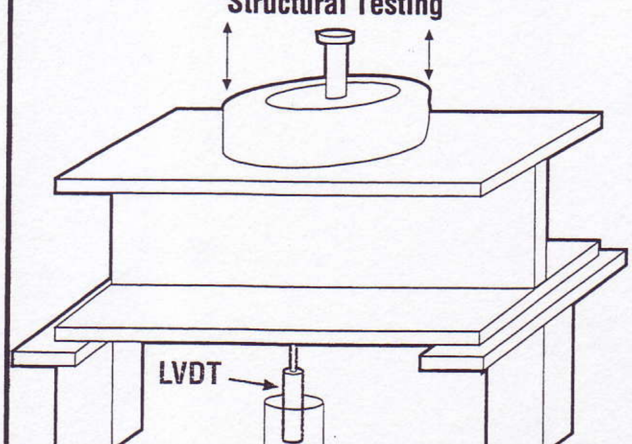
Actuator feedback is critical in controlling paper coating thickness.

Bottle Height Inspection



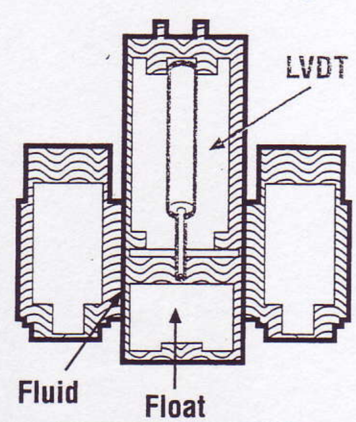
Height is measured by the position of a vertical rod coming in contact with the mouth of the bottle.

Structural Testing



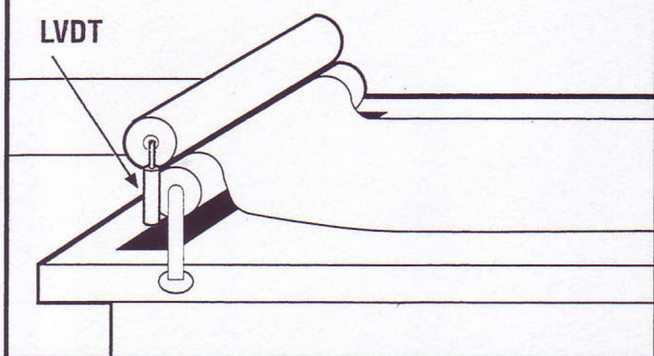
Durability of structural components are continuously checked under conditions of stress.

Automotive Suspension System



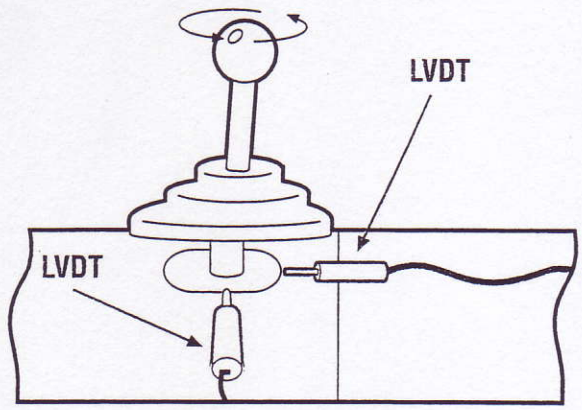
Measures fluid level through float position inside a valve, providing stable vehicle ride performance.

Roller Thickness Measurement



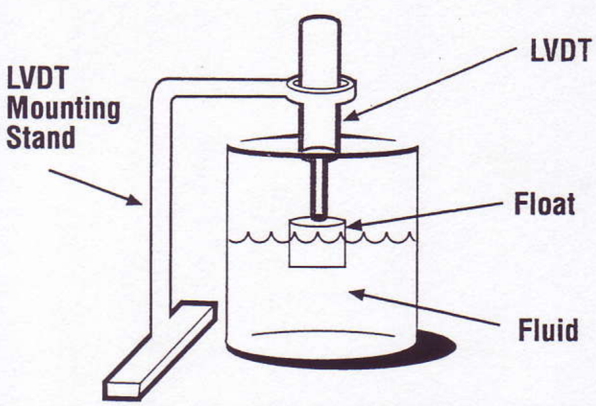
Creates proper spacing between rollers to achieve desired material thickness.

Robotics Joystick Control



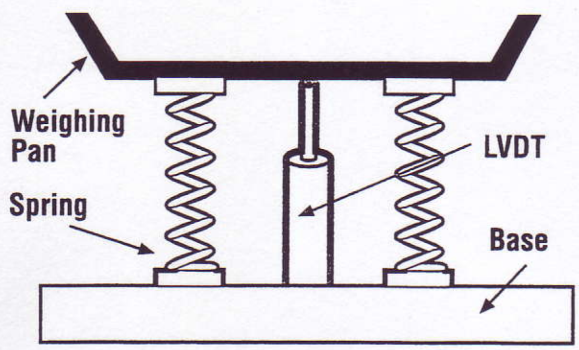
Provides position control in multiple axes as robotic arm follows operator's arm movement.

Specific Gravity Probe



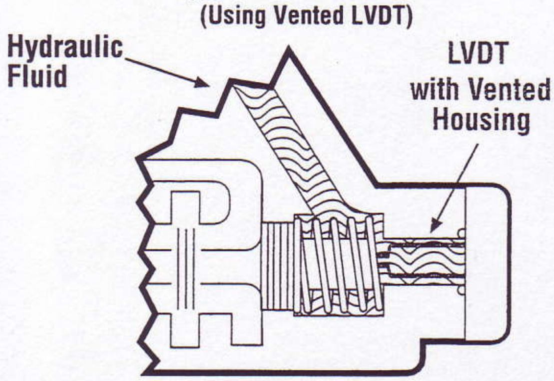
Fluid density is determined by measuring the position of a float suspended in a known flux liquid.

Weighing Systems



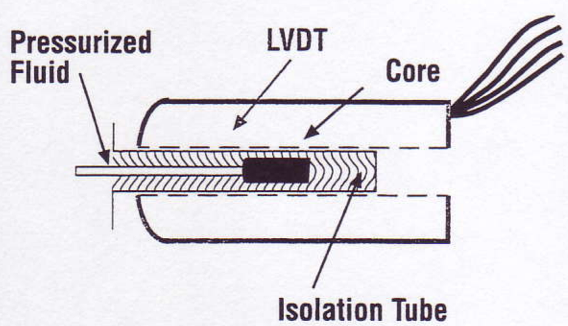
Knowing the deflection of a spring and the spring constant leads to the calculation of weight or force.

Hydraulic Servovalves
(Using Vented LVDT)



Immersed in compatible hydraulic fluid, a vented housing equalizes pressure throughout the LVDT.

Hydraulic Servovalves
(Using Isolation Tube)



An isolation tube houses the moving core and protects the LVDT from the high pressure fluid.

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